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Exploratory Trials with Pre-pressed
Fillings for Hollow Charges

D. McKenzie
J. Trower

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REPORT 8/54

Exploratory Trials with Pre-pressed Fillings for Hollow Charges

D. McKenzie, J. Trower

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Summary

The penetration in mild steel of hollow charges with pre-pressed fillings has been examined. At five inch stand-off 80/20 RDX/TNT was found to give much the same performance as 60/40 RDX/TNT.

The performance of composite charges was also explored with interesting results, the most striking being that with a TNT., air or wood centre section the performance was much enhanced.

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1. Reference numbers

2. Introduction

It had been shown incontrovertibly that the results with the 2.62" diameter copper cone with cast RDX/TNT owed much of their inconsistency to the casting, due to variation in the pourability of the RDX/TNT from batch to batch, variation due to the operator and to the method of filling. Hence it was decided that to progress at all these filling variables should be eliminated. The obvious answer was the use of pre-pressed charges which could be checked before filling into the weapon. These pressed charges were easily made and duplicated. They lent themselves to experiments designed to show the effect of composition on penetration and from this the next step was an exploratory series of trials with charges of a composite nature. See Diagrams 1, 5 and 6. A technique of pressing these composite charges was evolved which allowed trials on charges composed of three different explosives as indicated in the sketches.

The practical side of the problem, that of application of the results to service weapons was given every consideration and this resulted, as a start to service application, in proposals for trials with the 3.5" H.E.A.T. head with wood blocks fitted over the apex of the cone and the normal cast filling for this weapon around and above the wood block. The work with wood blocks was attractive because of the possible applicability to fillings poured or pressed.

3. Methods employed

3.1. Tools. The pressing tools were made of a good quality steel, e.g. of the 'vibrac' type with a fairly high tensile strength and capable of taking on a good mirror finish. Diagram No.1 shows the tools used for the standard pellet for the 2.62"-diam. cone, and Diagrams Nos. 3, 4 and 5 those for the composite pellet.

3.2. Materials. The composition used for the charges was RDX/TNT with an RDX content from 0% to 80%. Compositions with RDX lower than 60% were made from 60/40 by diluting with TNT when molten, recasting and then milling the resultant biscuit in a stainless steel end-runner mill whose pestle was lifted from the pan approximately 1/4". Little attention was paid to the degree of milling at this stage other than ensuring that the resultant powder was homogeneous. The range of size of the powder was from 20 mesh to 200 mesh.

For compositions of higher RDX content than 60%, RDX was added to molten 60/40 RDX/TNT to give the required RDX content, the mixture incorporated hot, cooled and milled as before.

3.3. Pressing

3.3.(a). Density and weight of pellet

The pellet volume to give a charge of total height 4.25" was calculated and a weight equivalent to this volume estimated for pellets of different composition based on a figure of 93% of the absolute density. For composite pellets the volume of each section was calculated and the weight estimated again based on 93% of the absolute density of the composition used.

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3.3.(b). The Production of Pellets

In order to ensure a good density distribution throughout the pellet the process of pressing from both ends of the pellet was adopted, viz. 'double-ending'. The mould was placed on a 0.6" C-collar so that the bottom former protruded 0.6" from its final position. The required weight of composition was poured into the mould as a loose powder, the long top drift inserted and a C collar placed on top of the mould to fix the final length of the pellet by limiting the intrusion of the drift on pressing. Pressure was applied until the top of the top drift was level with the top of the collar. The bottom collar was now removed and pressure again applied so getting 'double ending'. This final pressure was approximately 7 tons per square inch on the pellet. The pellet was obtained by up-ending the mould on the top drift, placing a C collar on top and so pressing the pellet upwards out of the mould.

A check on the density and composition of the pellet was obtained by cutting a half inch section from the centre, dicing into $3/8 \times 3/8 \times 1/2$ " portions and analysing. A typical 60/40 pellet analysis is shown in diagram No.2.

3.3.(c). The Production of composite pellets

The pressing tools for making the composite pellet are shown in diagrams 3, 4 and 5. The following is a description of the sequence of operations.

- (1) The mould was placed on a 0.6" long C collar with former 1 partly inserted into the mould to get the 'double ending' effect as in the case of the single explosive pellet. The calculated weight of composition was filled into the mould around the former, drift 1 placed in position as indicated in the sketch and the cylindrical drift pressed home to a distance defined by the collar on top of the mould. The 0.6" C collar was removed and pressure applied. The pressure again being approximately 7 tons/sq. inch.
- (2) Former 1 was then removed and former 2 inserted, drift 1 being left in position. The second increment of explosive was then added to the mould around the shank of former 2. A bottom C collar was placed in position and pressure applied to the top via a cylindrical drift No.2 to a position determined by the top C collar. The bottom C collar was then removed and pressure again applied to 'double end' the second increment.
- (3) The middle increment of explosive was completed in much the same way as increment 2.
- (4) The complete pellet of three explosives was now extruded upwards as in 3.3(b).

3.4. Penetration test

Diagram 6 shows the set up assembly for the penetration trial. The cone, of copper, is 2.62" diameter and 2.62" high. It is a pressed cone 0.07" thick and weighing 149 ± 5 grms. The container is $3/16$ " thick and the cone is secured by a screwed ring. The charge is placed on a card tube of the requisite length to provide the specified stand-off. This is set on a stack of mild steel plates each plate 6" x 6" x $1/4$ " thick. The charge is detonated via the C.E. pellet by a No.8 Briska detonator and a Bickford fuze. The plates are examined after firing and the total number penetrated noted, the hole in each plate measured and the total volume of the hole estimated. The slug was then recovered and weighed, its position in the stack being noted.

4. Results

4.1 Effect of composition at 5" stand-off.

It was decided that as this work constituted exploratory trials only a 5" stand would provide a guide to performance under practical conditions. As a first step charges of RDX/TNT with composition from TNT to 80/20 RDX/TNT were pressed; all were made to the same percentage of their absolute density, namely 93%.

The charges were fired with the following results.

TABLE I. One Explosive Charge. 5" stand-off

Composition RDX/TNT	Penetration Inches	'K' Factor	Volume of Cavities ccs.	Slug			Entry Hole cms.
				Wt. Gms.	Distance from top of slug to top of stack. cms.	Length cms.	
0/100	10 $\frac{1}{2}$	4.0	49.6	94.5	7.6	8.4	30 x 33
20/80	12 $\frac{3}{8}$	4.7	63.1	39.5	10.2	6.2	35 x 35
40/60	12 $\frac{3}{4}$	4.85	73.7	93.5	11.4	10.4	35 x 37
60/40	13 $\frac{1}{4}$	5.05	71.8	101.0	12.1	12.2	33 x 34
80/20	13 $\frac{1}{4}$	5.05	86.0	92.5	13.3	10.7	45 x 46

The similarity between 60/40 and 80/20 in depth of penetration led to some examination of the effect of stand off as a side issue only in the main exploration. The following table of results indicates the difference between 80/20 and 60/40 at different stand-off distances.

4.2 Effect of Stand-off Distance

TABLE 2.

Composition RDX/TNT	Stand off Ins.	Penetration Ins.	'K' Factor	Volume of Cavity ccs.	Slug			Entry Hole cms.
					Wt. Gms.	Length cms.	Distance from top of slug to top of stack. cms.	
60/40	5.0	13 $\frac{1}{4}$	5.05	71.8	101.0	12.2	12.1	33 x 34
80/20	5.0	13 $\frac{1}{4}$	5.05	86.0	92.5	10.7	13.3	45 x 46
60/40	7.8	14 $\frac{5}{8}$	5.65	72.2	79.5	8.6	10.8	-
80/20	7.8	15.0	5.75	76.3	91.0	10.7	12.7	37 x 37
60/40	10.0	15 $\frac{1}{2}$	5.90	76.3	85.0	8.9	11.4	33 x 35
80/20	10.0	16 $\frac{1}{4}$ +	6.2 +	81.8	82.0	7.9	-	35 x 40

4.3 Composite Charges.

A number of composite charges were pressed as described before and fired in the normal manner.

Results are detailed in Tables 3, 3a and 3b below. The composition of the charges is given as percentage of RDX in the appropriate section, the outer sector being named first, e.g. 40/60/80 indicating 40/60 RDX/TNT in the outer sector of the charge, 60/40 RDX/TNT in the middle section and 80/20 RDX/TNT in the inside sector.

Table 4 is merely a rearrangement of the results in Tables 3, 3a and 3b, to show the effect of various changes in the composition. The composition figure of the sector of the charge which is varied is underlined.

TABLE 3. Composite Explosive Charges. High Percentage of RDX Outside.

No.	Composition % RDX Outside/Middle/ Inside	Average % RDX	Pene- tration inches	'K' Factor	Volume of Cavity ccs.	Slug Details		
						Wt. Gms	Lth Cms	Distance top of slug to top of stack
1	40/0/0	21.0	13 $\frac{1}{2}$	5.15	62.5	98.0	11.5	12.7
2	40/40/0	33.1	13 $\frac{1}{2}$	5.25	69.0	97.0	9.8	12.1
3	80/0/0	42.0	13 $\frac{1}{2}$	5.25	81.5	88.0	9.5	13.3
4	80/40/40	61.0	14	5.35	67.6	98.5	11.4	14.0
5	60/60/40	56.5	14	5.35	79.5	81.0	7.9	11.4
6	80/80/60	76.5	14 $\frac{1}{2}$	5.45	83.5	99.0	11.7	14.0
7	80/80/40	73.0	14 $\frac{1}{2}$	5.45	72.8	86.5	9.5	15.2
8	60/0/0	32.3	14 $\frac{1}{2}$	5.53	70.2	97.0	11.5	14.0
9	60/60/0	49.5	14 $\frac{1}{2}$	5.6	77.1	90.0	9.4	14.0
10	80/80/0	66.5	14 $\frac{1}{2}$	5.6	80.7	89.0	9.5	13.3
11	80/60/60	70.3	15	5.8	95.1	100.5	13.0	15.9
12	80/60/40	67.0	15	5.8	-	-	-	-
13	60/40/0	43.7	15	5.8	71.2	78.0	7.9	12.7
14	80/40/0	54.6	15	5.8	73.8	94.0	9.0	14.6
15	80/60/0	64.0	16	6.1	92.5	91.0	11.5	17.8

TABLE 3a. Composite Explosive Charges. Low Percentage of RDX Outside.

No.	Composition % RDX Outside/Middle/ Inside	Average % RDX	Pene- tration inches	'K' Factor	Volume of cavity ccs	Slug Details		
						Wt. Gms	Lth Cms	Distance top of slug to top of stack
16	0/60/60	29.5	12 $\frac{1}{2}$	4.65	64.1	92.0	7.7	8.2
17	0/80/80	39.5	12 $\frac{1}{2}$	4.65	64.4	95.0	14.2	11.4
18	20/80/80	48.3	12 $\frac{1}{2}$	4.75	62.9	98.0	12.2	10.8
19	0/0/60	11.3	12 $\frac{1}{2}$	4.85	55.8	104.0	11.8	8.9
20	40/40/60	43.8	13 $\frac{1}{2}$	5.05	65.2	98.0	10.7	11.4
21	40/40/80	47.5	13 $\frac{1}{2}$	5.15	57.0	65.0	6.1	11.4
22	60/60/80	63.5	13 $\frac{1}{2}$	5.15	-	-	-	-
23	40/80/80	59.5	13 $\frac{1}{2}$	5.25	71.0	95.0	12.7	13.3
24	60/80/80	70.0	13 $\frac{1}{2}$	5.25	74.3	92.0	9.7	12.7
25	60/60/95	66.5	14	5.35	-	-	-	-
26	40/60/80	53.5	14 $\frac{1}{2}$	5.45	-	-	-	-

TABLE 3B. Sandwich Charges.

No.	Composition % RDX Outside/Middle/ Inside	Average % RDX	Pene- tration inches	'K' Factor	Volume of cavity ccs	Slug Details		
						Wt. Gms	Lth Gms	Distance top of slug to top of stack
27	0/60/0	18.6	12 $\frac{1}{2}$	4.75	59.2	92.0	8.0	9.5
28	60/0/60	42.7	14	5.35	63.6	102.0	11.4	12.1

TABLE 4. Rearrangement of Tables 3 and 3a.

	Composition	Penetration ins.	'K' Factor	% Increase over 60/60/60	Volume of Cavity ccs.	Entry Hole mms. ^{1/16}
a	80/80/80	13 $\frac{1}{4}$	5.05	0	86.1	45 x 26
	80/80/ <u>60</u>	14 $\frac{1}{4}$	5.45	8	83.5	30 x 30
	80/80/ <u>40</u>	14 $\frac{1}{4}$	5.45	8	72.8	25 x 26
	80/80/ <u>0</u>	14 $\frac{3}{4}$	5.6	11	80.7	20 x 21
b	60/60/60	13 $\frac{1}{4}$	5.05	0	71.6	33 x 34
	60/60/ <u>80</u>	13 $\frac{1}{2}$	5.15	2	-	-
	60/60/ <u>40</u>	14	5.35	6	79.5	32 x 34
	60/60/ <u>0</u>	14 $\frac{3}{4}$	5.6	11	77.1	25 x 26
c	40/40/40	12 $\frac{3}{4}$	4.85	-4	73.4	35 x 37
	40/40/ <u>60</u>	13 $\frac{1}{4}$	5.05	0	65.2	32 x 34
	40/40/ <u>80</u>	13 $\frac{1}{2}$	5.15	2	57.0	32 x 33
	40/40/ <u>0</u>	13 $\frac{3}{4}$	5.25	4	69.0	25 x 25
d	0/ 0/0	10 $\frac{1}{2}$	4.0	-21	49.6	30 x 33
	<u>40</u> / 0/0	13 $\frac{1}{2}$	5.15	2	62.5	25 x 29
	<u>80</u> / 0/0	13 $\frac{3}{4}$	5.25	4	81.5	23 x 27
	<u>60</u> / 0/0	14 $\frac{1}{2}$	5.5	9	70.2	29 x 31
e	0/60/0	12 $\frac{1}{2}$	4.75	-6	59.2	25 x 30
	<u>60</u> /60/0	14 $\frac{3}{4}$	5.6	11	77.1	25 x 26
	<u>80</u> /60/0	16	6.1	21	92.5	27 x 30
f	40/40/0	13 $\frac{3}{4}$	5.25	4	73.4	25 x 25
	<u>60</u> /40/0	15	5.8	15	71.2	27 x 28
	<u>80</u> /40/0	15	5.8	15	73.8	28 x 30
g	0/80/80	12 $\frac{1}{4}$	4.65	-8	64.4	40 x 40
	<u>20</u> /80/80	12 $\frac{1}{2}$	4.75	-6	62.9	33 x 35
	<u>80</u> /80/80	13 $\frac{1}{4}$	5.05	0	86.1	45 x 46
	<u>40</u> /80/80	13 $\frac{3}{4}$	5.25	4	71.0	30 x 31
	<u>60</u> /80/80	13 $\frac{3}{4}$	5.25	4	74.3	30 x 31
h	80/ 0/0	13 $\frac{3}{4}$	5.25	4	81.5	23 x 27
	80/ <u>80</u> /0	14 $\frac{3}{4}$	5.6	11	80.7	20 x 21
	80/ <u>40</u> /0	15	5.8	15	73.8	28 x 30
	80/ <u>60</u> /0	16	6.1	21	92.5	27 x 30
i	0/ 0/0	10 $\frac{1}{2}$	4.0	-21	49.6	30 x 33
	<u>40</u> /40/0	13 $\frac{3}{4}$	5.25	4	69.0	25 x 25
	<u>80</u> /80/0	14 $\frac{3}{4}$	5.6	11	80.7	20 x 21
	<u>60</u> /60/0	14 $\frac{1}{4}$	5.6	11	77.1	25 x 26

TABLE 5. Non-Explosive Central Sector.

Type Diagram 8	Compo- sition	Pene- tra- tion. ins.	'K' Factor	Volume of Cavity	Slug Details			Entry Hole cms.
					Wt. gms.	Length cms.	Distance from top plate cms.	
Air Type 1	60/60/-	11 $\frac{3}{4}$	4.5	39.4	63.0	9.5	8.3	23 x 28
Air Type 1a Short cone	60/60/-	9 $\frac{1}{2}$	3.6	23.4	-	-	0.0	6 x 12
Air Type 2	60/60/60	16 $\frac{1}{4}$	6.2	69.0	69.0	8.8	14.6	20 x 22
Wood Type 3a	60/60/60	15 $\frac{1}{2}$	5.9	66.8	-	-	0.0	15 x 17
	80/60/60	16	6.1	72.5	87.0	8.5	14.0	32 x 40
	80/60/0	16 $\frac{1}{4}$	6.2	68.1	83.0	9.0	15.2	20 x 20
Wood Type 2a	60/60/60	14 $\frac{3}{4}$	5.6	60.2	64.5	8.2	14.6	14 x 16
Wood Type 3	60/60/-	12 $\frac{1}{2}$	4.8	49.1	71.0	7.6	7.0	37 x 42

5. Discussion of Results

5.1. Single Explosive Charges

Table 1 gives the surprising result that there is very little difference between 60/40 and 80/20 RDX/TNT. Increase of stand-off distance from 5 inches to 10 inches, Table 2, does differentiate between them but the 5 inch stand-off was chosen as being something like one of practical service significance and hence the results at this stand-off were used as the main platform for experiment and discussion is centred on this.

There have been many views with much experiment about the value of increasing the percentage of RDX in RDX/TNT and its effect on penetration. It can be assumed that with the cast charges the advantage was real but there is no doubt that many previous conclusions from results using cast fillings have been over-shadowed by filling difficulties, variation of RDX/TNT from batch to batch, in content of RDX, pourability and quality of TNT, control of temperature of filling and temperature of store to be filled, variation of operator, variation of method of filling, to enumerate a few.

It might be that with cast charges the increased penetration with fillings of higher RDX content was obtained because of the ability of the richer RDX/TNT's to attain a high velocity of detonation easier than the RDX/TNT of the low RDX content, in the same distance. The difference would be aggravated by the tendency of the more pourable RDX/TNT's to settle out at the top of the filling, leaving RDX/TNT of still lower RDX content with more difficulty in reaching maximum velocity of detonation. The effects of settling are minimised of course with the use of heading techniques in casting. With pressed charges the filling variations are cancelled and the resultant explosive is more easily initiated than a casting of corresponding RDX content so the figures of penetration with pressed charges are probably more nearly the true ones for the 5 inch stand-off. Whatever the argument there is little doubt but that the pressings provide more comparable figures. The distance chosen between the exploder and the top of the cone is a factor, of course, and 1.6" was chosen as being something like a practical length. Whether or not a longer distance here would give better values could be investigated but as far as the present series of experiments goes it can be accepted that the pressed charge has enhanced the penetration of the 60/40 compared to the 80/20. The greater energy of the jet of the 80/20 charge is shown by the increase in cavity volume over that with the 60/40 charge. See diagram 7. From the contour of the cavity it could be inferred that there was some interference with jet formation resulting in a wide-mouthed cavity and a subsequent loss in penetration. This view is supported by the results of the charges with the non explosive centres, the contours of whose cavities do not show the wide-mouthed feature. See diagram 7a. With increased stand-off and 80/20 charges, or for that matter charges of 60/40, this wide mouth is still a feature of the cavity and belies the view that there has been any change in jet contour due to increase of stand-off although there appears to have been an improvement in the coherence of the jet or some other like property resulting in increased penetration.

5.2. Composite charges.

- (i) Consideration of Tables 1 and 3 shows, in the first instance, that only very few results from a good assortment of composite charges gave less penetration than the standard 60/40 (or 80/20) charge; in fact it could be said that it was difficult to get lower results than that of the 60/40. Only those composites with TNT or 20/80 RDX/TNT in the outside 'third' gave the lower results; all other composites fired gave an equal or better penetration than 60/40. Again, the results considered are those using a stand-off of 5 inches. It might be inferred from this that uniformity of composition is not a very important factor and that differences in composition within fairly wide limits are permissible.

- (ii) It can be seen that overall RDX percentage of the charge is no guide to its efficiency as measured by penetration; charges Nos. 1 and 2 with 21% and 33% of RDX respectively are striking examples of this, showing no fall in penetration compared to 60/40 RDX/TNT.
- (iii) Another conclusion from consideration of results as a whole is that lowering the RDX content of the outside explosive in relation to that of the inner sections gives a lower penetration.
- (iv) Further, with practically all the combinations tried, decreasing the RDX content of the innermost section improved the penetration. This is a most interesting result. As can be seen from Table 4, Items a, b, c etc., the best result is got with TNT alone in the inside section. This leads to the view that wave shaping was the principle influencing the penetration in the experiments but the straightforward explanation was taken that the reason for charges like 60/60/0, outside/middle/inside, giving improved results over 60/60/60 was because the inside section of explosive of higher velocity of detonation interfered with the effective collapse of the cone. It could be argued then that 40/60/80 (No.26, Table 2) should not have given an improved result over 60/60/60. In charges like this one explanation could be that the fast inside is fast enough to avoid the interference effect and that wave shaping is the predominating feature. It is obvious that there are other factors and that more comprehensive trials would require to be done to explain this and other points. However, the fact remains that with central TNT an improved result was obtained and this led to experiments with air and wood blocks in the central section.
- (v) Table 5, restricted though it is, is, nevertheless, very significant. Arguing from the results as shown in table 4, no explosive was included in the middle section of a 60/40 charge and the charge detonated as shown in diagram 8, 1. The result was a drop in penetration. This result was with a normal height of cone. When the same type of charge was fired with a short cone, see diagram 8, 1a, the result was a further drop in penetration. Whether it could be argued that in the first charge the 'excess' length of cone influences the functioning and was, in effect, another instance of the tail wagging the dog, is problematical, but might be worth following up from the theoretical stand-point. Still persisting in the view of interference of the central explosive, a charge of 60/40 was drilled as in diagram 8.3a but with air instead of wood and the firing results showed a surprising advance on the standard charge. A cavity with chamfered bottom was made to another charge, (see diagram 8.2) with no very different result. From these, and with cast charges in view, the next step was to introduce a wood block in the charge in place of air. Results again showed an appreciable advantage over the normal charge so much so that the wood block principle was considered with a bigger scale trial in a service weapon, and the 3.5" H.B.A.T. was chosen for a trial with shaped wood blocks attached to the cone on the same scale as used with the pressed charges. The trial is scheduled to be done at an early date.

It can be seen from the sketch of the types of these charges that below the exploder is only 0.4" of explosive; in all cases 60/40 RDX/TNT was used here. This length would seem to be very short and better results

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might be expected with a longer length. It was the object in the investigation to do exploratory trials only, and hence many side lines were disregarded, as this was, with the intention of returning to them when general principles had been established.

6. Future trials

Even confining proposals for work in the future to 5 inch stand-off trials a considerable programme of work could be done on a wider scale than that described. However, it is apparent that there are several lines of definite immediate interest. Not the least of them is further trials on the wood block principle for application to cast charges, which are, at the moment, the normal Service store. Variation of diameter of wood block, of chamfer angle at the bottom, of chamfer angle at the top, and of length of wood block, are possible factors to settle. The effect of varying the height of the cone to coincide with a varying overlap of the wood block on it, is also another aspect.

With regard to composite charges investigation of these with wood blocks on or along the lines of charge No.6, table 5, could be done.

Generally, the work with the pressed charges has emphasised the advantages of such a method of filling and points to the necessity for a full scale trial filling of a Service weapon with this type of charge.

7. Acknowledgements

Thanks are due to C.M.A.D. (Mr. Feist) for the generous allocation of stores for the experiments.

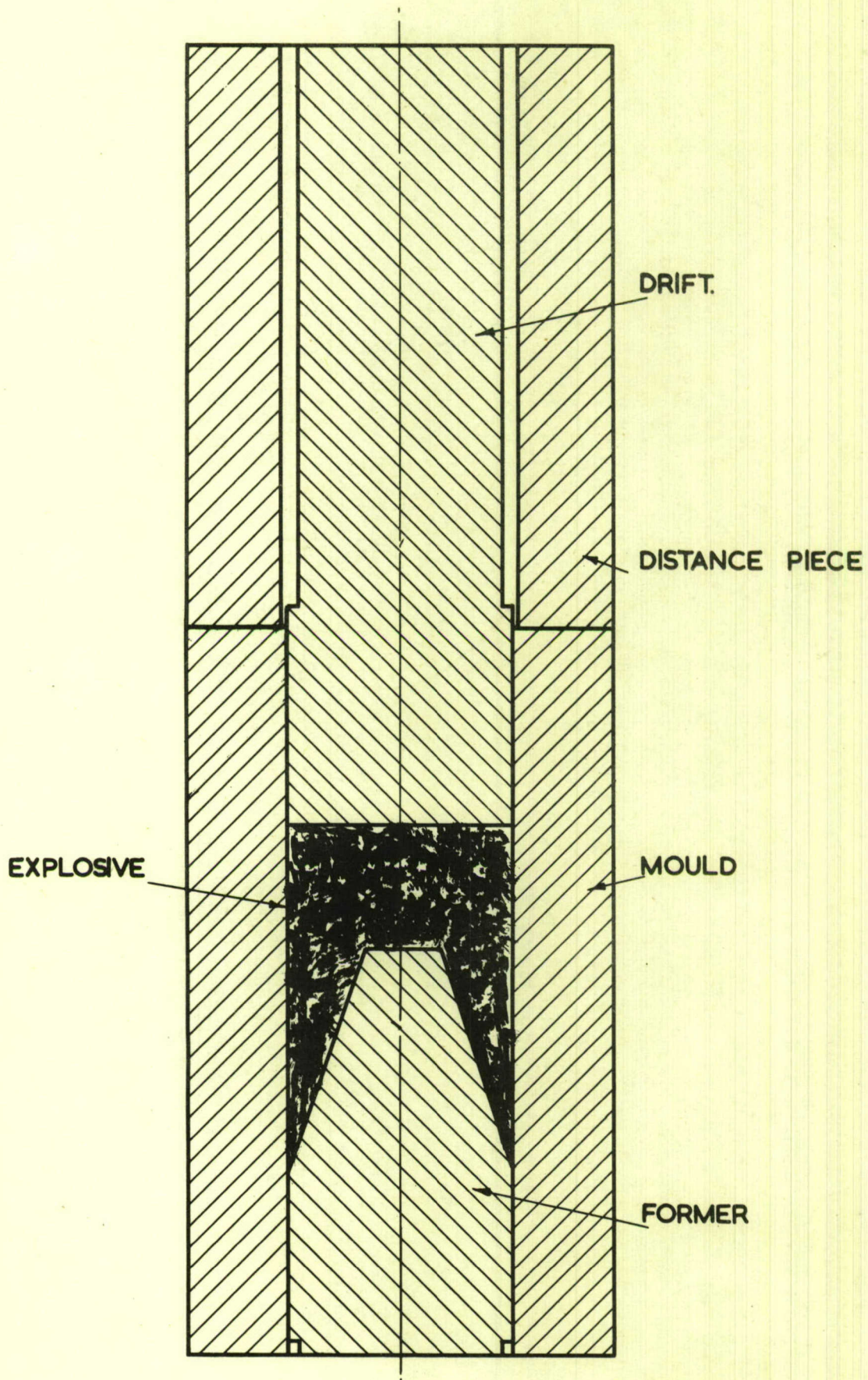


FIG. I

CHARGE N° I.

3.5" H. E. A. T.

CAST FILLING 60/40 R.D.X./T.N.T.

2.62" CONE.

PRESSED CHARGE 60/40.

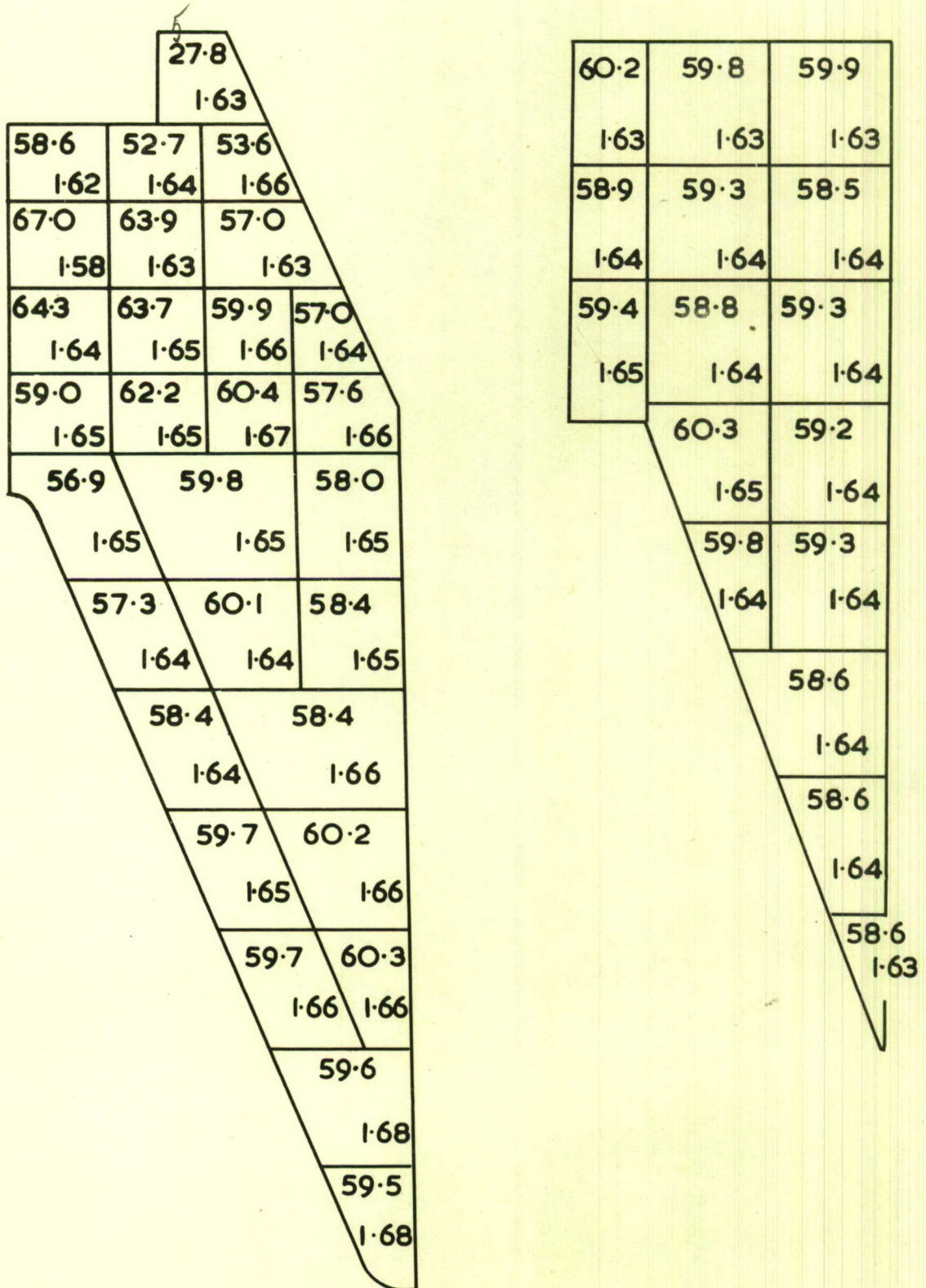
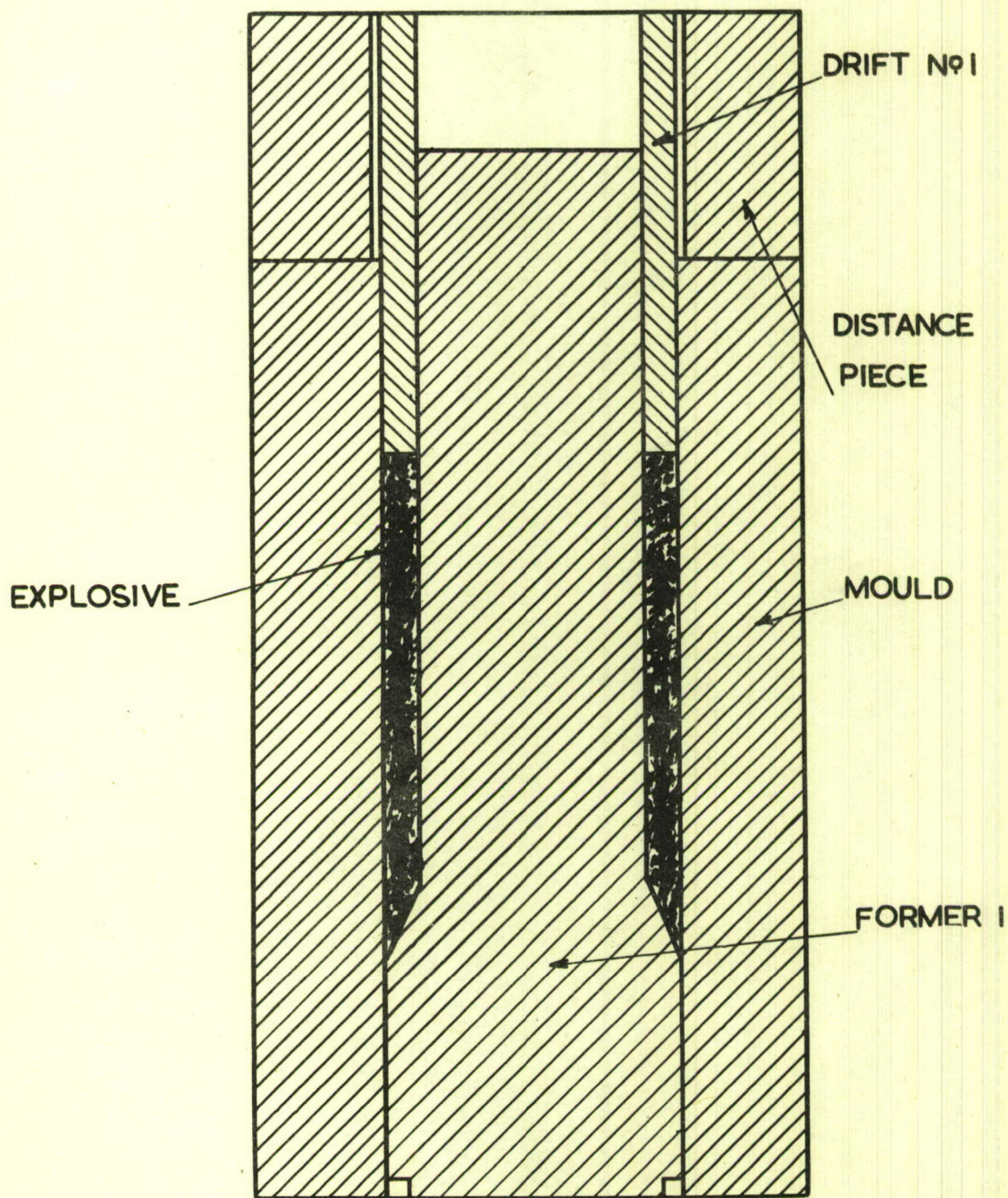
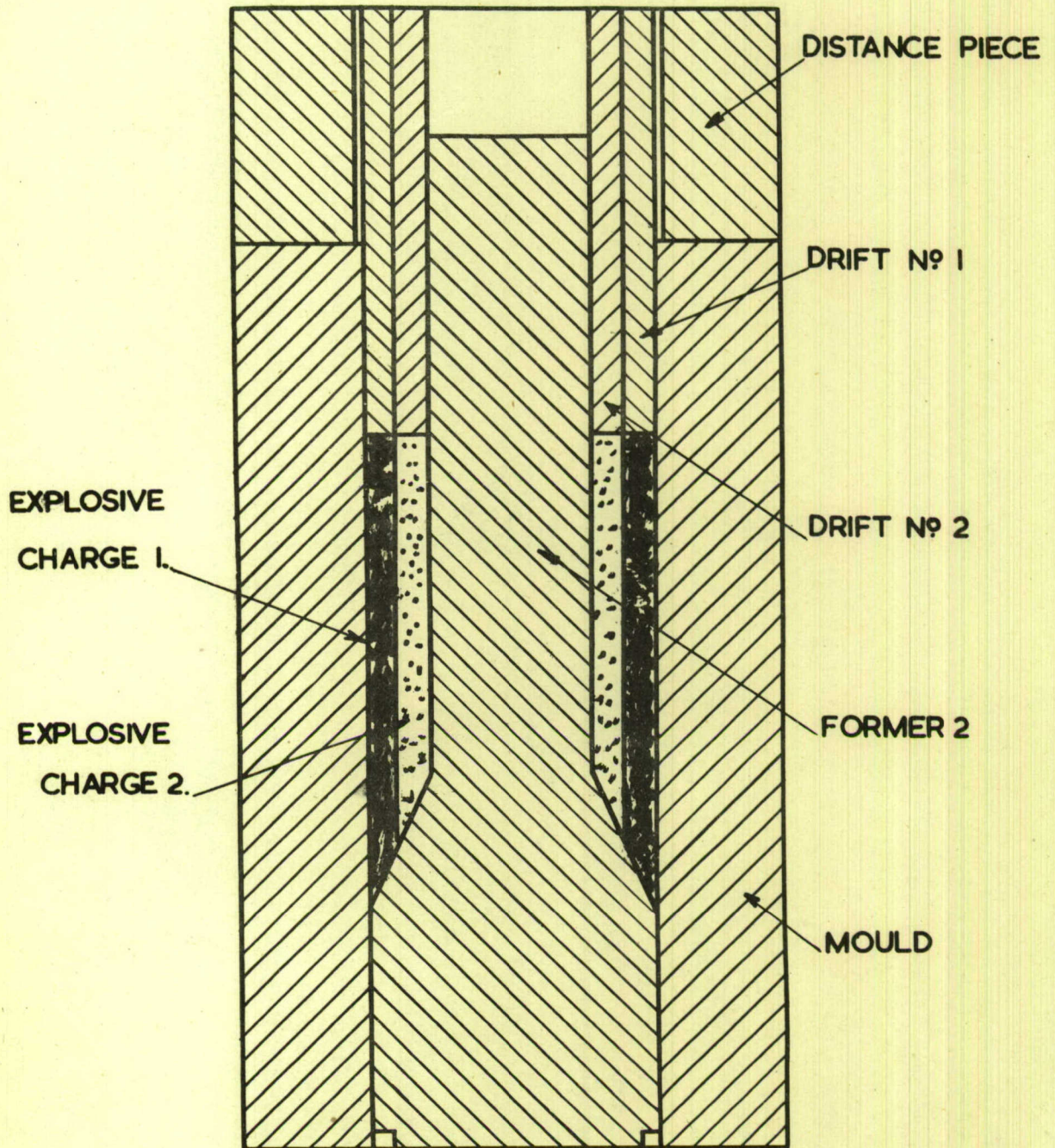


FIG 2.



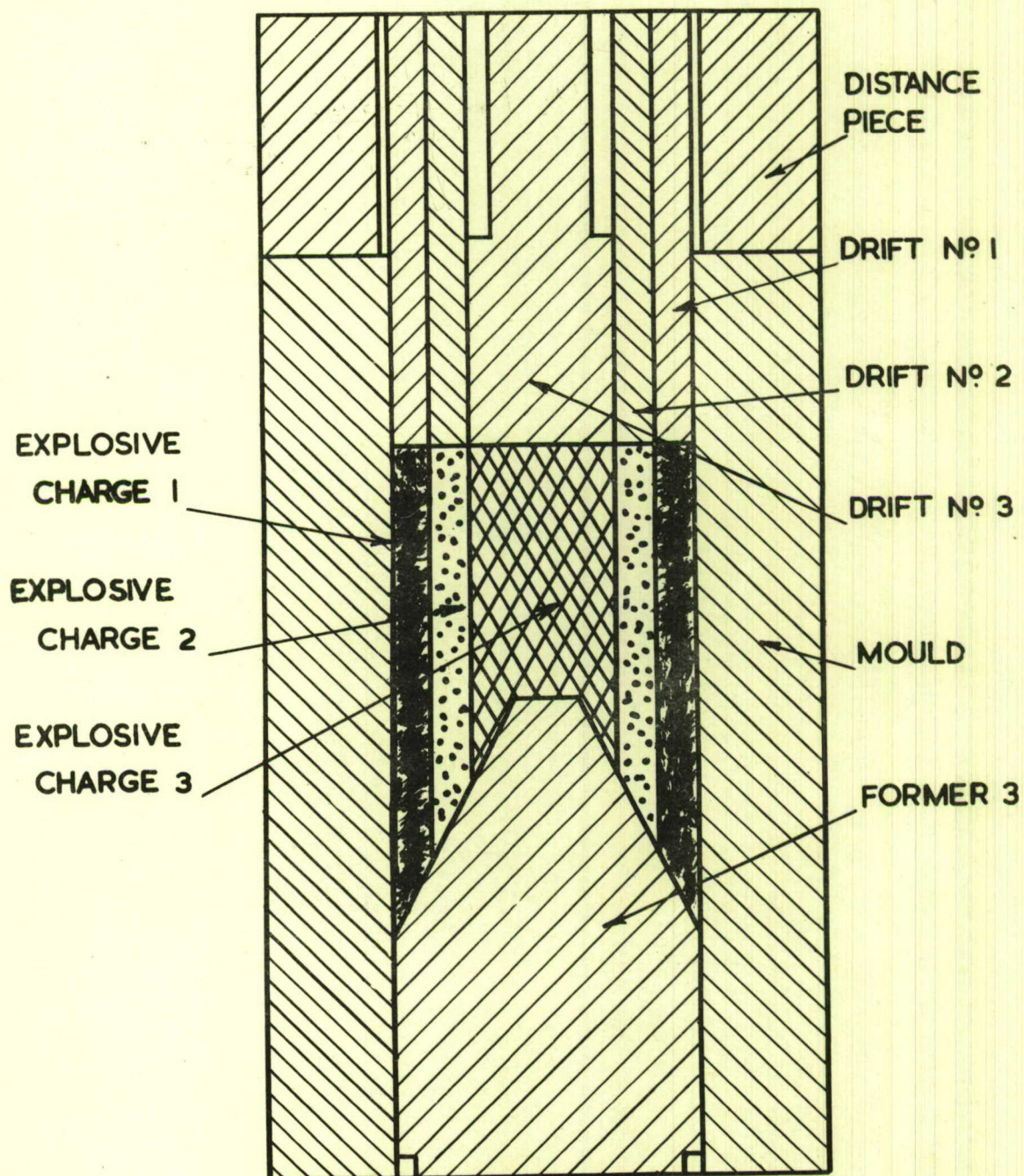
CHARGE No 2
OPERATION 1.

FIG. 3



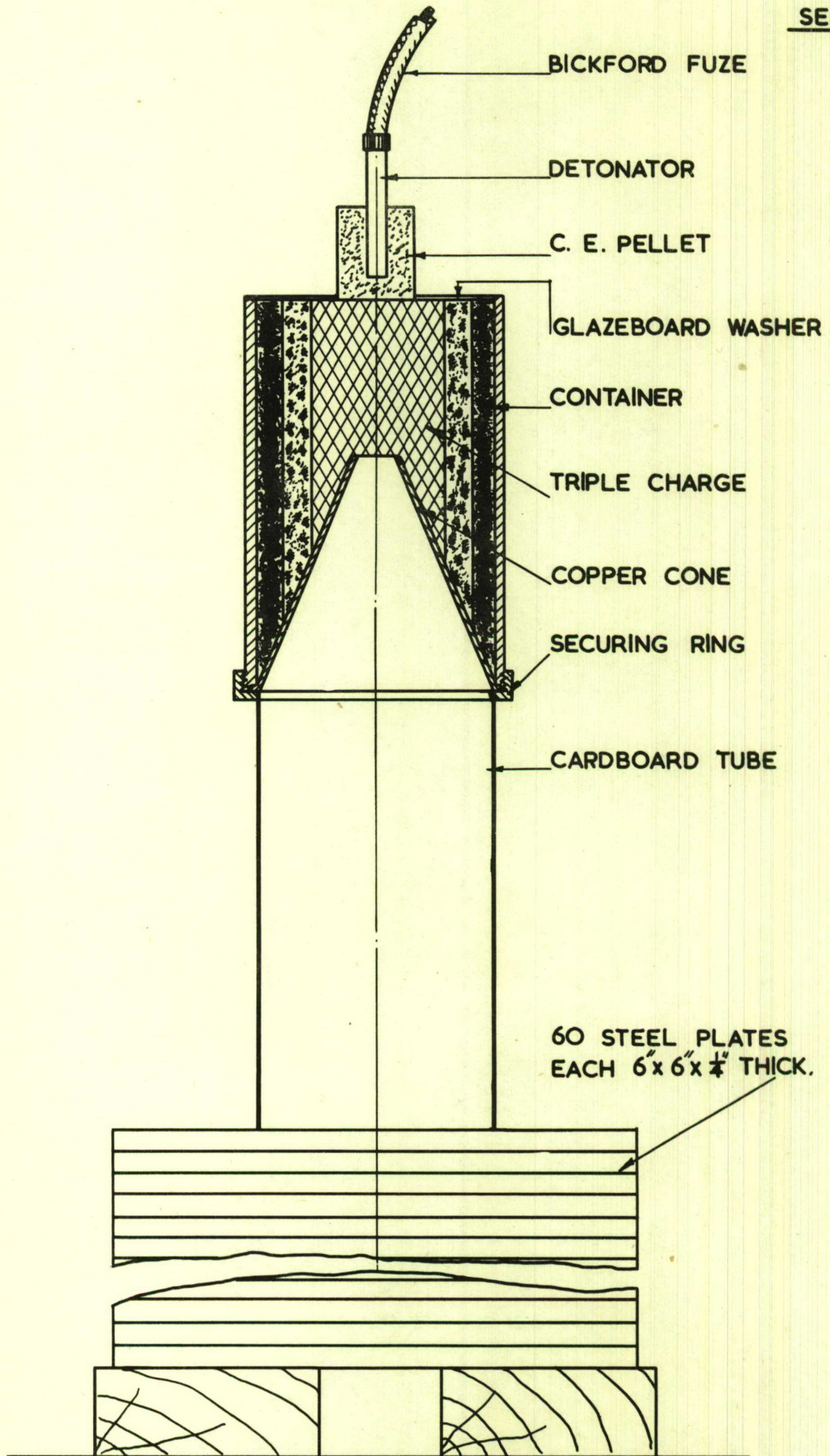
CHARGE N° 2
OPERATION 2

FIG. 4



CHARGE N° 2
OPERATION 3

FIG. 5



ASSEMBLY FOR
FIRING TRIAL

FIG 6.

FIG. 7

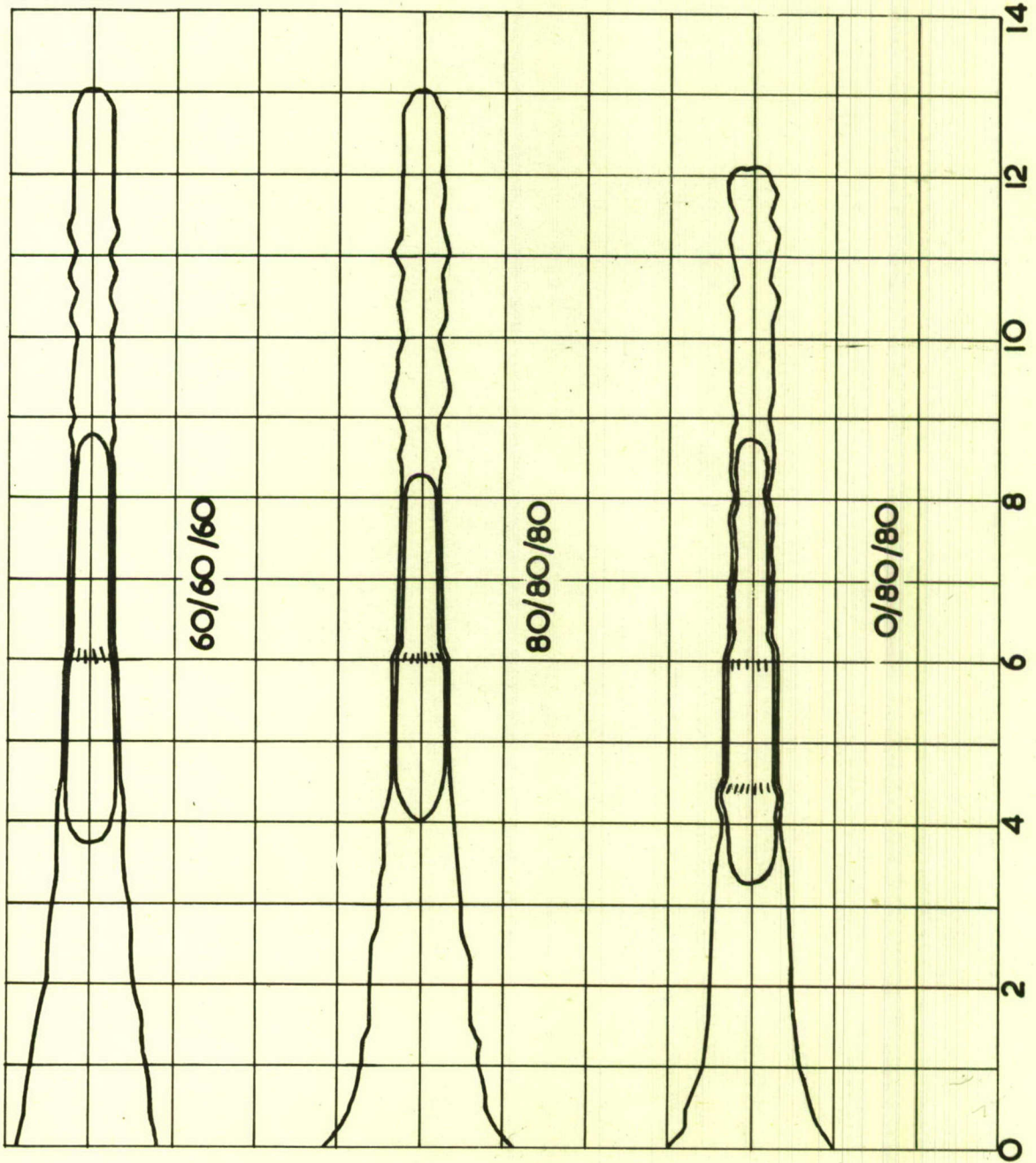
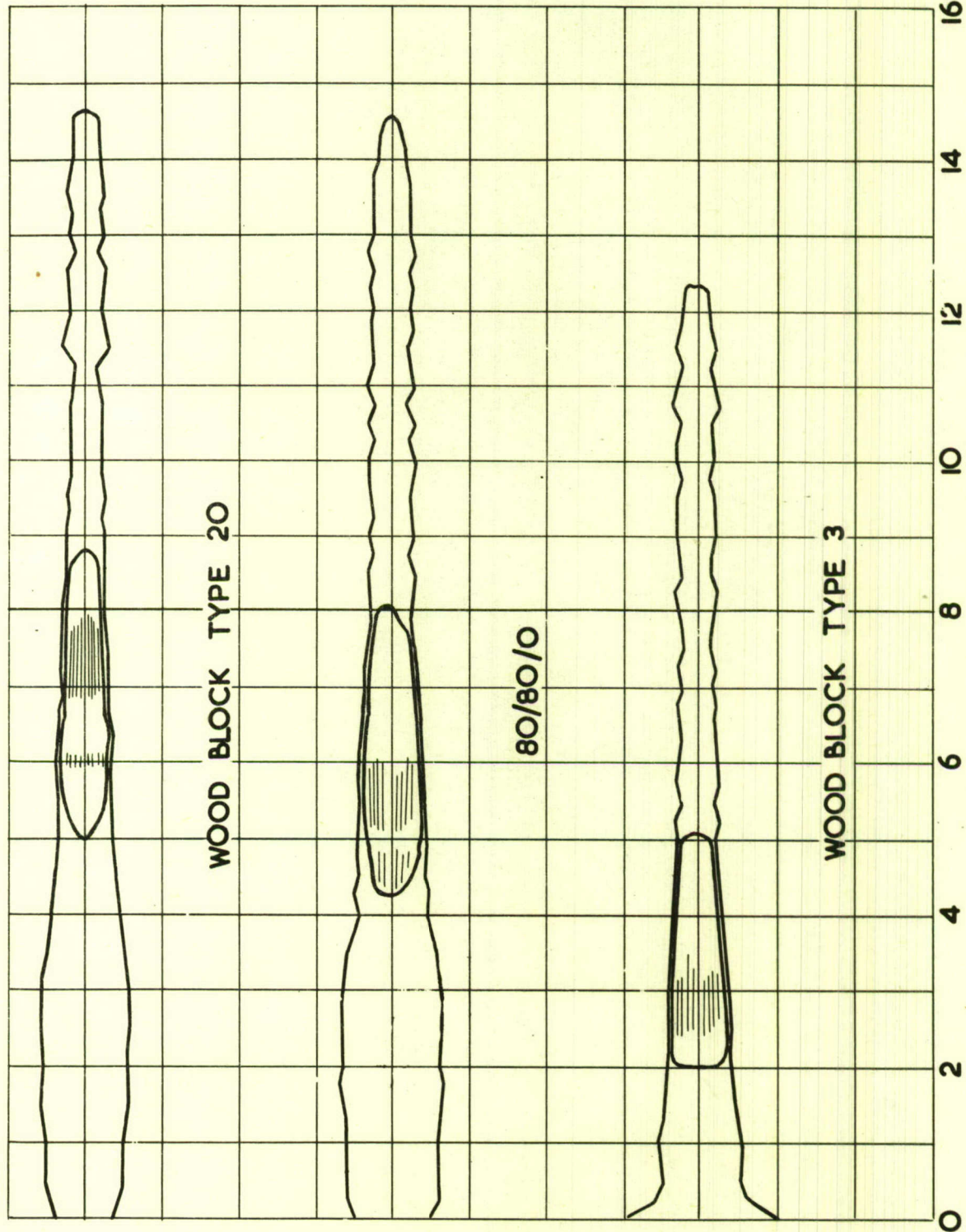


FIG. 7a



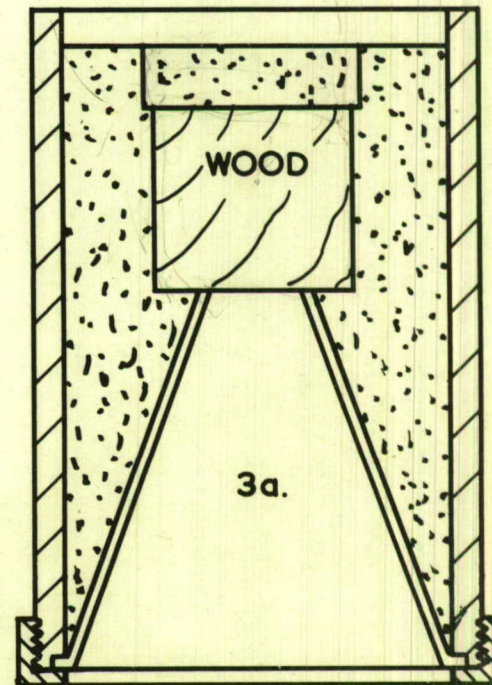
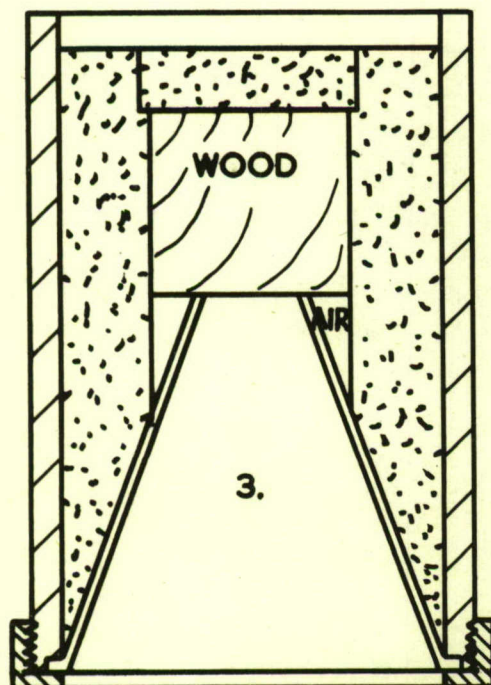
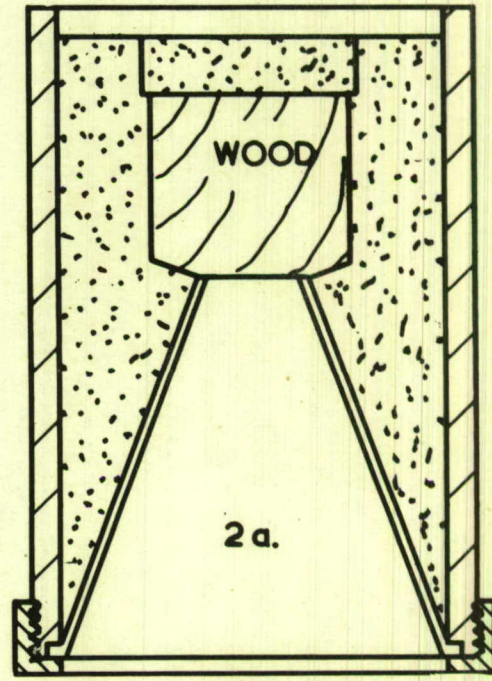
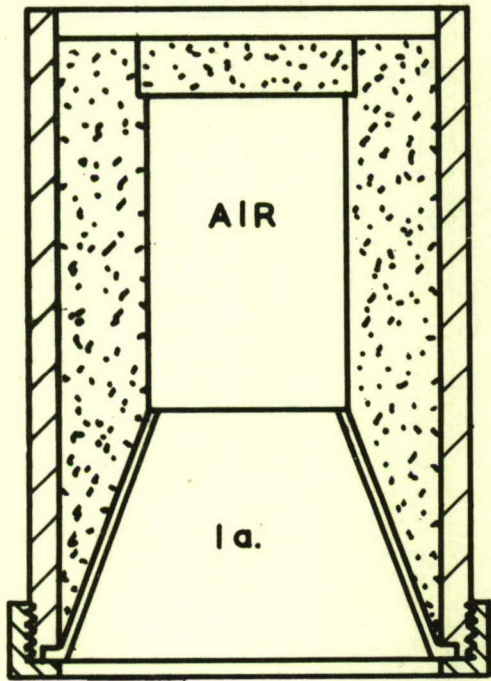
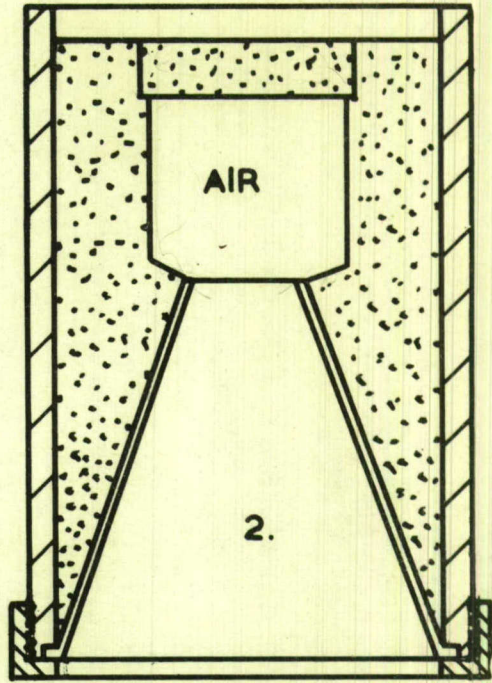
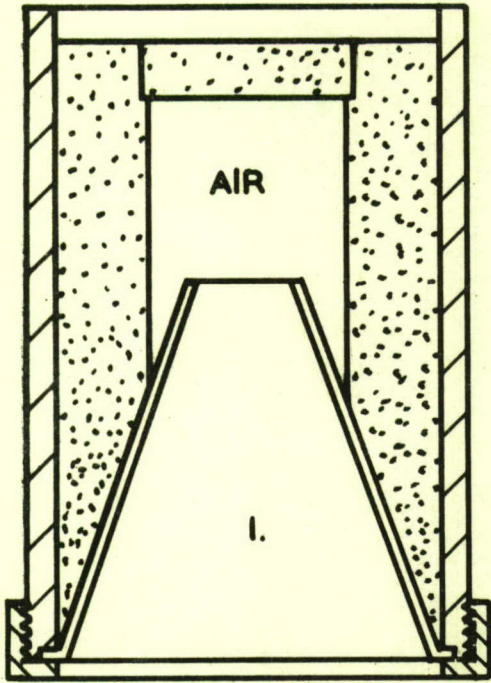


FIG. 8.

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